PATENT SPECIFICATION

DRAWINGS ATTACHED

865,084

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International Classification: —A62b.

COMPLETE SPECIFICATION

Altitude Compensated Continuous Flow Oxygen Regulator

We, THE ARO EQUIPMENT CORPORATION, a Company incorporated under the Laws of the State of Ohio, United States of America, of Enterprise and Trevitt Streets, Bryan, Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to a continuous flow oxygen regulator and has for its object to provide a regulator which is altitude compensated in such manner as to secure a desirable flow-to-altitude relationship which more closely approaches a theoretically ideal relationship than has been possible with regulators as hitherto constructed. The regulator of the invention would be particularly useful when used in the oxygen supply system of a passenger aircraft.

According to the invention, a continuous flow altitude-compensated oxygen regulator is provided with a secondary pressure-reducing stage comprising a plurality of aneroid-operated metering valves which are disposed to function in parallel and are arranged to open in sequence.

The secondary pressure reducing stage may comprise a plurality of sections disposed in parallel with each other, each section incorporating a plurality of aneroid-operated metering valves which are disposed to function in parallel and are arranged to open in sequence.

An embodiment of the invention applied to the oxygen supply system of a passenger aircraft will now be described with reference to the accompanying drawings, in which: —

Fig. 1 is a plan view of an altitude-compensated continuous flow oxygen regulator constructed according to the invention.

Fig. 2 is a side elevation of Fig. 1, intermediate portions of the regulator being cut away to conserve space on the drawings.

Fig. 3 is an enlarged vertical sectional view on the line 3—3 of Fig. 2, a portion of the lower right-hand corner of the figure being on a section line indicated 3a—3a in Figs. 2 and 5.

Fig. 4 is an enlarged vertical sectional view on the line 4—4 of Fig. 2.

Fig. 5 is a plan view of the base of the regulator shown on a reduced scale with respect to Fig. 1, portions thereof being broken away to show certain connecting passageways in the base.

Fig. 6 is an enlarged sectional view on the line 6—6 of Fig. 1.

Fig. 7 is an enlarged sectional view on the line 7—7 of Fig. 2 which sectional view is also indicated by the line 7a—7a of Fig. 1.

Fig. 8 is a diagrammatic view of the regulator for the purpose of explaining its operation; and

Figs. 9 to 15 are representative curves with respect to oxygen flow in relation to altitude, outlet pressure in relation to altitude and other factors involved in the design of our regulator.

On the accompanying drawings, and referring first to Fig. 8 showing the complete regulator system, the regulator has a plurality of chambers therein as follows: —

A. Inlet chamber
B. First stage chamber
C. Outlet chamber
D. First stage back pressure chamber
E. Aneroid chamber

These chambers may also be identified throughout Figs. 3 to 7 by the same reference characters A, B, C, D and E applied to both the chambers and to the connecting passageways which will be later described.

The chambers referred to are formed by a base and certain housings illustrated in detail in Figs. 1 to 7. The base is indicated at 16 and at the right-hand end thereof in Fig. 2 is a first stage housing 20, a first stage back pressure housing 22 and a cap 24 which are suitably secured together and to the base 16 by screws as illustrated. A first stage valve housing 26 (see Fig. 4) is interposed

between the base 16 and the housing 20. Suitable gaskets are provided between the housings 20 and 26 and the housing 22 and 24 to prevent leakage, whereas the edge of a first stage diaphragm D^3 serves as a gasket between the housings 20 and 22. The cavities within the housings 22 and 24 communicate through a port 25 shown in Fig. 4.

An oxygen inlet 28 (see Fig. 5) at the right-hand end of the base 16 is connected with a source of oxygen supply under high pressure such as 2,000 PSI and the inlet communicates with a passageway 30 in the base 16 from which a port 32 extends upwardly (Fig. 4) to connect with a passageway 34 leading into a cavity 36 in the first stage valve housing 26. The top of this cavity is closed by a valve seat 40 in which is a valve stem guide 44 for a valve stem 42. A spring-closed first stage metering valve 38 is normally closed against the valve seat 40 and the stem 42 serves as a thrust pin between the valve 38 and a pivoted lever arm 46.

The arm 46 is operatively connected to the diaphragm D^3 which is spring depressed as illustrated in Fig. 4, and the tension of the spring may be adjusted by an adjusting screw 48 located within the cap 24.

The chamber B is provided with a spring-closed relief valve 50 to automatically open and relieve any excessive pressure resulting from malfunctioning of the regulator. The relief valve 50 thereby prevents any dangerous build-up in pressure within the chamber B. The outlet from the relief valve 50 terminates in a threaded boss 52 adapted to have a line connected therewith for discharge of the relieved oxygen to the outside of the aircraft.

Referring to Fig. 8, a pair of second stage spring-closed metering valves 54 and 54a are provided between chambers B and C. These are also shown in Fig. 3, mounted in an aneroid housing 70, and their construction is similar to the valves 38 in Fig. 4. They are mounted in a second stage valve housing 56 interposed between the base 16 and an aneroid housing 70. The housing 56 has cavities 58 therein which are connected with the chamber B in the housing 20 by passageways 60 and 62 in Fig. 4 and 62, 63 and 64 in Fig. 3. The passageway 62 extends through the base 16 as shown in Fig. 5 and a test plug 66 may be provided for removal so that the chamber B can be connected with test equipment for testing and adjusting the regulator after it is assembled. The ends of the passageway 62 are plugged as at 68 (see Fig. 5).

In Fig. 3 is shown the second stage valves 54 and 54a which are located on the line 3—3 of Fig. 2, and to the left of the housing 70 in which they are mounted are two similar housings 70 of the same construction as shown in Fig. 3. The three housings 70 are connected in parallel for increasing the supply of oxygen e.g. to 100 passengers, whereas one of the sections as shown in Fig. 3 will supply only 50 passengers, on the basis of each pair of valves 54 and 54a supplying 50 passengers but one extra pair of valves being always provided as a safety factor.

The aneroid housing 70 covers the second stage metering valves 54 and 54a and provides the chamber C as well as a chamber E in conjunction with a cover plate 72. The chamber C within the housing 70 communicates through passageways 57 and 59 with a passageway 112 in the base 16 terminating in outlets 110. Aneroids A^1 and A^2 are located in the chamber E and are operatively connected with the valves 54 and 54a by plungers 74 and 76. The plungers are sealed relative to a central partition 78 of the aneroid housing 70 by diaphragms D^1 and D^2. The diaphragms are not sectioned in Fig. 3 and are shown as heavy black lines in Fig. 8 for clarity. The partition 78 has perforations 80 and 82 therein for the diaphragms D^1 and D^2 respectively and these perforations define the areas of the diaphragms, the effective areas of the aneroids A^1 and A^2 being somewhat larger than the areas represented by the perforations 80 and 82. Also, it will be noted that the area of the diaphragm D^1 is greater than the area of the diaphragm D^2, the purpose of which will hereinafter appear.

Each aneroid housing 70 has a vent 84 to atmosphere in a boss 85 of the housing 70 which also serves as a test port. For convenience in testing the regulator while mounted in the aircraft, this port is threaded so that a vacuum line can be attached and altitudes can be simulated within the aneroid chamber E without removing the entire regulator and placing it in an altitude chamber. By having one test port 84 for each of the three sections illustrated, they can be tested individually.

Referring to Fig. 6, the chamber D is closed to atmosphere by a spring-closed back pressure relief valve 86. The tension of the spring may be adjusted by a nipple 88 threaded into the cap 24 and the adjustment retained by a lock nut 90. The back pressure relief valve 86 in the first stage back pressure chamber D acts to protect the system against a build up of pressure within the system. If the outlet pressure increases, the first stage pressure would also increase and would continue to do so until the entire system would be at a pressure equal to the inlet gas pressure. To prevent this, the relief valve 86 is set at a predetermined pressure limiting the final system pressure, in case of a failure such as any leakage or failure of a second stage valve which would cause the outlet pressure in the chamber C to increase, because of a tube connection 92 between the chambers C and D. The tube connection 92 has its lower end entering a passageway 98 as in Fig. 7

which communicates with a passageway 112 (chamber C). A holding clip 93 is provided for the tube 92 and a suitable O-ring seal is used as illustrated. The tube has its upper end passing through a fitting 96 and entering the cap 24 as shown in Fig. 6, communicating therein with the chamber D by means of a passageway 94. This connection feeds back the pressure from chamber C against the back pressure side of the diaphragm D^3 to maintain the proper balance of pressures for obtaining the desired pressure regulation and oxygen quantity flow dependent upon altitude as reflected in the expansion of the aneroids A^1 and A^2 as they open the second stage metering valves 54 more or less depending upon altitude affecting the aneroids through the vents 84 to atmosphere. Seals between the base 16 and housings 26 and 56 are effected by suitable O-rings around the passageways 32, 59, 60 and 63 (see Figs. 3, 4 and 5). These seals are shown stippled in Fig. 5.

The performance of a continuous flow oxygen system such as disclosed operates preferably as depicted by the curve C^1 in Fig. 9 wherein the base line indicates altitude and is graduated in thousands of feet. The vertical line indicates flow in standard litres per minute and is the recommended mass flow received by each passenger or user of the oxygen regulator. In Fig. 8, a supply line 106 is shown from the chamber C to the passengers and each passenger is supplied through an orifice 108, and the line 106 being connected of course to one of the three outlets 110 of the chamber C shown in Fig. 3 and 5.

Since the flow to each passenger is controlled by an orifice or other type of flow restrictor, it is necessary for the regulator itself to change its outlet pressure in comparison with ambient pressure. When converting the passenger mass flow into terms of pressure required to produce this flow through the passenger orifice, it is found that the resulting pressure-altitude curve C^2, as shown in Fig. 10, is not linear as the curve C^1 in Fig. 9. The vertical line in this case indicates outlet pressure in pounds/square inch absolute. In order for the system to be efficient without using a quantity of oxygen greater than required, it is important that the regulator outlet performance curve be as close as possible to the requirements represented by the curve C^2 of Fig. 10. Thus, we have the desired performance curve C^2 as a starting point for the design of a regulator.

In producing an altitude compensated regulator the only changing force that can be utilized is that shown by the absolute pressure curve. This is shown in Fig. 11 at C^3, the vertical line indicating atmospheric pressure absolute. As will be noted the curve C^3 is not a linear curve either, and curves in the opposite direction compared to the desired curve C^2 of Fig. 10.

If a standard control section of this type of regulator were tested, the resulting pressure-altitude curve would be approximately the curve C^3 of Fig. 11 in place of the desired curve C^2 of Fig. 10. The slopes of the curves can be changed by varying the area ratios as between the effective areas of the aneroid A^1 and diaphragm D^1 or aneroid A^2 and diaphragm D^3. The location of the curves can be changed by adjustment of the initial positions of the aneroids A^1 and A^2 by means of their adjusting screws 100, the latter being provided with lock nuts 101 and protective cap nuts 102.

In order to overcome the foregoing problems we utilize the design shown in Fig. 8 with reference to the chambers A, B and D which comprise a first reduction stage, and the chambers C and E which comprise an altitude compensated second stage. The total number of second stage sections, represented by the number of pairs of second stage metering valves, is dependent upon the application. For instance, if each second stage section is rated at approximately 50 persons per section and the requirement is for 100 people, two sections are required plus one for safety, giving a total of three. Only one section is shown in Fig. 8, whereas three are shown in Fig. 1 for 100 people.

The oxygen supply enters the regulator at the inlet 28 of Fig. 5 (chamber A in Fig. 8) and flows through the first stage metering valve 38, the pressure of which is controlled by the spring loaded diaphragm D^3 which, when loaded to a predetermined point, moves to release the pressure on thrust pin 42 through lever 46, and allow the spring loaded valve 38 to close on to the valve seat 40 and stop the inlet flow of oxygen to the first stage or chamber B. When the pressure in chamber B is lower than this predetermined point the spring loaded diaphragm D^3 moves to open valve 38 by increasing the pressure exerted on thrust pin 42 by lever 46.

The first stage pressure in chamber B flows to the second stage metering valves 54 and 54a. These valves in turn control the flow of oxygen to the outlet chamber C and consequently to the outlets 110, the supply line 106 and the orifices 108 for the aircraft passengers. Since the valves 54 and 54a are controlled by the aneroids A^1 and A^2 respectively, with increasing altitude these aneroids expand and react through the diaphragms D^1 and D^2 to control the valves 54 and 54a and thereby the outlet pressure in the aircraft's oxygen distribution system connected with the chamber C.

The slopes of the curves C^4 and C^5, as with the previously mentioned curve C^3, can be varied and are controlled by the ratio of the sensing area of diaphragm D^1 and the

effective area of the aneroid A^1 and also of sensing area D^2 and aneroid A^2. As will be noted, the ratio of area A^1 to area D^1 is quite small; hence, a rather flat curve results as shown at C^4 in Fig. 12, whereas a greater ratio as between A^2 and D^2 produces a steeper curve such as C^5 in Fig. 13. When two altitude compensated second stage metering valves operate in parallel as in Fig. 8, it is possible to provide that the resultant curve is a composite C^{41} plus C^{51} as in Fig. 14.

We have illustrated the curve C^2 of Fig. 10 (representing the desirable curve) by dotted lines in Figs. 12, 13 and 14 to show that the slopes of curves C^4 and C^5 approximately match portions thereof and the curves C^{41} and C^{51} of Fig. 14 therefore produce a composite curve that quite closely follows the curve C^2 even though the curvatures are opposite. Thus the combination of two aneroids A^1 and A^2 with their diaphragms D^1 and D^2 approximately produce the curve C^2.

By the use of additional aneroid-second stage valve combinations the curve C^2 may be even more closely approached, as illustrated in Fig. 15, wherein the curves C^{41} and C^{51} are shown and a third curve C^6 is produced by including in the or each section a third aneroid and diaphragm combination (not shown) which extends the operating curve of the regulator beyond that illustrated in Fig. 14. This is especially desirable for higher altitudes as the curve C^2 continues to swing upwardly. Thus, in a regulator using sections comprising three or more second stage aneroid-valve combinations it is possible to use more than just two curves as described in connection with Figs. 13 and 14 to result in a final curve even more closely compared to the desirable curve C^2 of Fig. 10.

The passenger orifices 108 of Fig. 8 control the flow of oxygen to each passenger. One of these orifices is in communication through suitable tubing with each pasenger's mask in the usual manner. The quantity of flow is dependent on the pressure drop across the orifice. This pressure drop is the difference between the ambient altitude pressure and the system pressure which is the same as the pressure in the second stage, or outlet chamber C.

Still referring to Fig. 8, the aneroid A^1 is preset by its adjusting screw so that on increasing altitude it makes contact with diaphragm D^1 before the aneroid A^2 makes contact with the diaphragm D^2. Therefore aneroid A^1 reacts through diaphragm D^1 to operate the valve 54, and a flow of oxygen is metered from the first stage chamber B to the outlet chamber C, to meet the pressure requirements of the aneroid A^1. As mentioned before, the ratio of the aneroid area to diaphragm sensing area is small, which is reflected as a flat curve such as C^4 for the lower altitudes.

With further increasing altitude the aneroid A^2 responds through the diaphragm D^2 to open the valve 54^a and meter oxygen flow from the first stage chamber B to the outlet chamber C. As shown, the ratio of the aneroid area A^2 to the diaphragm area D^2 is quite great, giving a steep curve for the higher altitude section C^5 thereof. After the aneroid A^2 takes over, the additional pressure reacting against the diaphragm D^1 allows the valve 54 to close so that all flow at high altitudes is metered through the valve 54^a.

The tubing connection 92 and passageways 98 and 94 allow the outlet pressure in the chamber C to react in the first stage back pressure chamber D against the back of the diaphragm D^3 which controls the first stage pressure in the chamber B to a given amount above the outlet pressure in the chamber C. This provides a constant pressure difference across the valves 54 and 54^a and results in a constant closing force or pressure effect on these valves even though the outlet pressure increases with higher altitude.

The intended function of an altitude compensated continuous flow regulator is to provide oxygen to the user in increasing amounts with increasing altitudes. This has heretofore been done with a single second stage metering valve type of regulator which controls the oxygen outlet pressure in the system fed to the passengers through aircraft mounted orifices. With increasing altitudes the regulator produces an increased outlet pressure which in turn through the orifice is breathed by the user. With this increased outlet pressure the pressure differential across the orifice is increased causing a greater flow of oxygen to the user. Such a regulator is not of the demand type in that it regulates the outlet pressure only and the aircraft orifice system meters the flow to each user, therefore the name "continuous flow" is applied to this type of system.

These prior regulators could not produce the desired performance curve C^2 of Fig. 10 whereas the use of a plurality of second stage, altitude compensated metering valves arranged in parallel and operating sequentially as herein disclosed can produce a close approximation, thereby using oxygen efficiently as well as automatically meeting more exactly the varying oxygen requirements at all altitudes. The first stage metering valve 38 of our regulator reduces the normal high (2,000 PSI) inlet pressure to a more usable pressure and the altitude compensated final reduction stage maintains a variable outlet pressure commensurate with the altitude requirements with a comparatively simple arrangement of second stage valve-aneroid combinations arranged in parallel but operating in sequence.

Some changes may be made in the construction and arrangement of the parts of our altitude compensated continuous flow oxygen regulator without departing from the scope of our invention.

WHAT WE CLAIM IS:—

1. A continuous flow altitude-compensated oxygen regulator having a secondary pressure-reducing stage comprising a plurality of aneroid-operated metering valves which are disposed to function in parallel and are arranged to open in sequence.

2. A continuous flow altitude-compensated oxygen regulator having a secondary pressure-reducing stage comprising a plurality of sections disposed in parallel with each other, each section incorporating a plurality of aneroid-operated metering valves which are disposed to function in parallel and are arranged to open in sequence.

3. A continuous flow altitude-compensated oxygen regulator comprising a first stage pressure-reducing valve which is located between an oxygen inlet and a first stage chamber, and which is controlled by a diaphragm responsive to pressure in said first stage chamber, an outlet chamber, a secondary pressure reducing stage comprising a plurality of second stage metering valves located between the first stage chamber and the outlet chamber and disposed to function in parallel for controlling the flow of oxygen between said chambers, each second stage valve having in combination therewith an associated aneroid for opening the valve in accordance with predetermined ambient pressure conditions, and the arrangement being such that said valves are opened in sequence by their aneroids as ambient pressure decreases.

4. A regulator according to Claim 3, wherein the secondary pressure-reducing stage comprises two metering valves, each with an associated aneroid.

5. A regulator according to Claim 3, wherein the secondary pressure-reducing stage comprises three metering valves, each with an associated aneroid.

6. A regulator according to Claim 3, 4 or 5, wherein each metering valve-aneroid combination has an associated diaphragm which is exposed on one side to the pressure in the outlet chamber and on the opposite side to ambient pressure, said diaphragm functioning in the sense to oppose opening of the valve by the aneroid and the effective areas of the respective diaphragms being of different ratios relative to their aneroids.

7. A regulator according to any of Claims 3 to 6 wherein the diaphragm which is responsive to pressure in the first stage chamber has one side presented to said chamber, and has its opposite side presented to a back pressure chamber which is in constant communication with the outlet chamber.

8. A regulator according to Claim 7, wherein the back pressure chamber is provided with a pressure relief valve.

9. A continuous flow altitude-compensated oxygen regulator comprising a first stage pressure-reducing valve which is located between an oxygen inlet and a first stage chamber, and which is controlled by a diaphragm exposed on one side to the pressure conditions in said first stage chamber and on the other side to pressure conditions in an outlet chamber, the flow of oxygen from the first stage chamber to said outlet chamber being controlled by a plurality of second stage metering valves arranged as a plurality of sections which are disposed in parallel with each other and with each section consisting of a plurality of valves, the respective valves of each section also being disposed to function in parallel with each other, and the first stage chamber and the outlet chamber being common to all said sections, each second stage valve having in combination therewith an associated aneroid for opening the valve in accordance with predetermined ambient pressure conditions, the arrangement being such that in each section the respective valves are opened in sequence by their aneroids as ambient pressure decreases, and the outlet chamber being provided with an oxygen outlet for each of said sections.

10. A continuous flow altitude-compensated oxygen regulator, constructed and operating substantially as herein described, and as shown in the accompanying drawings.

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Chartered Patent Agent.

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Fig.1.

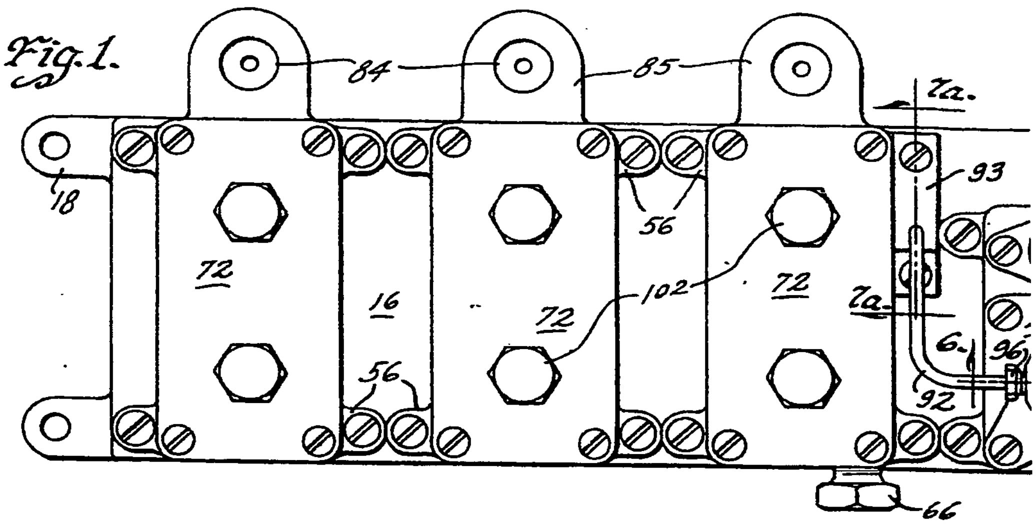
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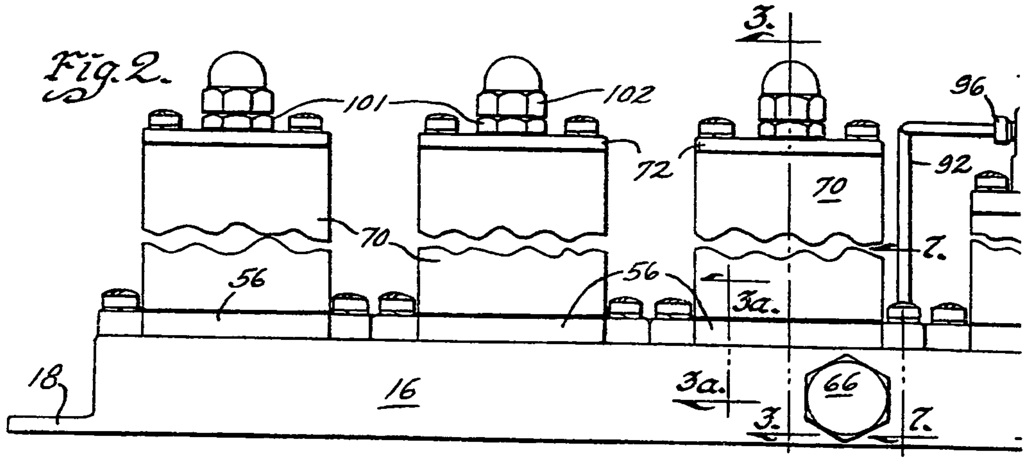
Fig.2.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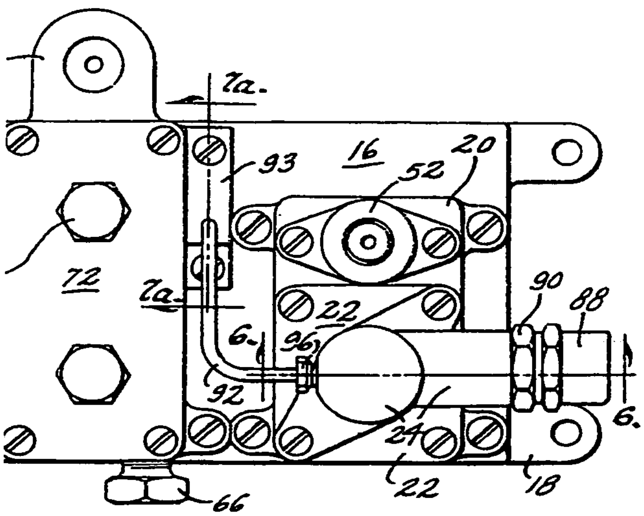

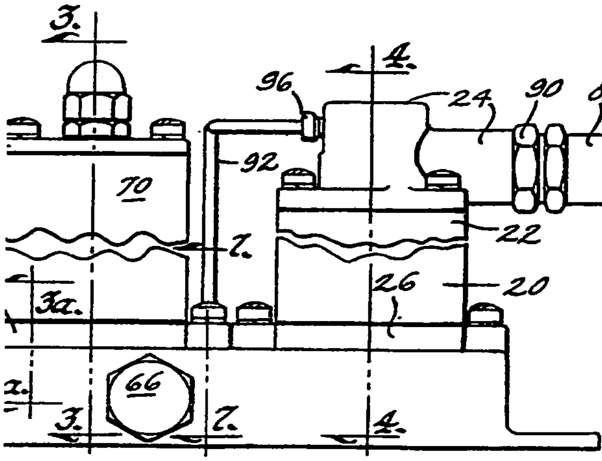

Fig.3.

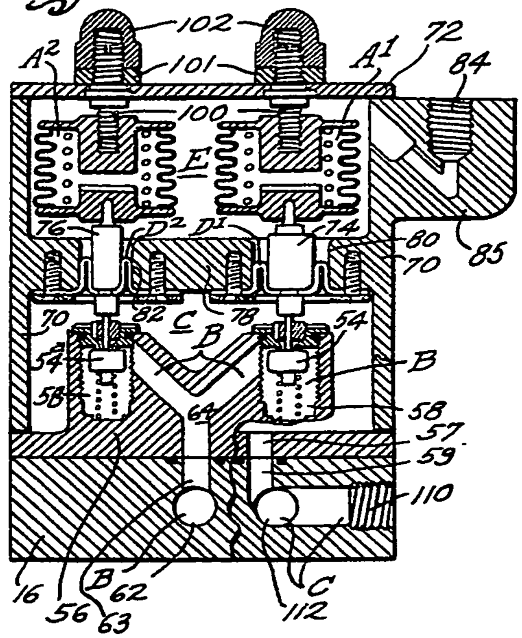

Fig.4.

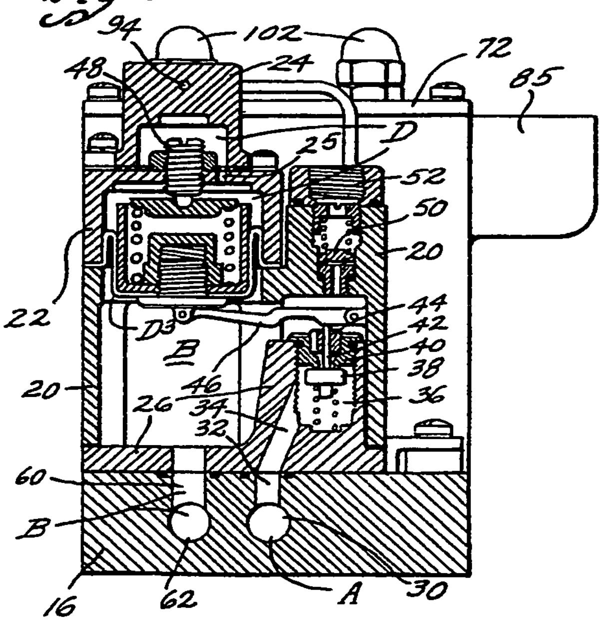

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Fig.1.

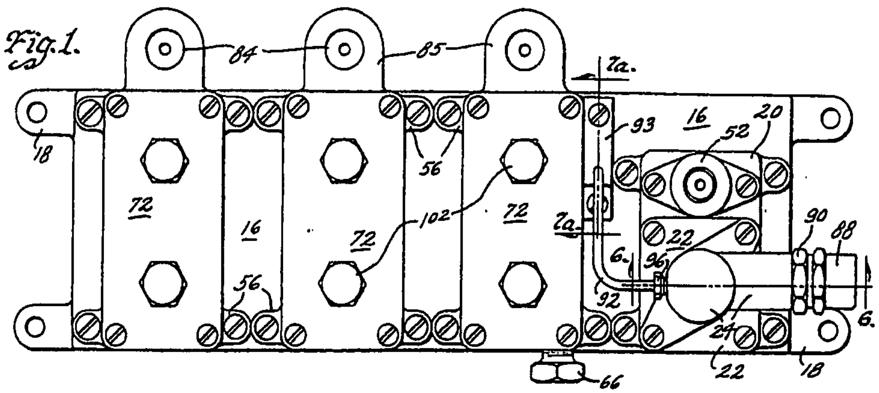


Fig.2.

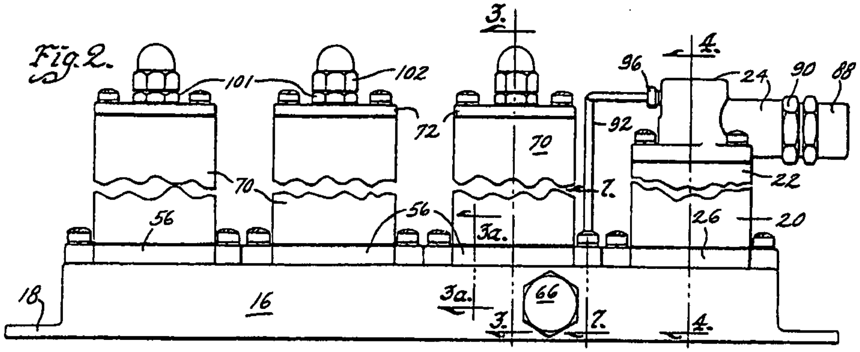


Fig.3.

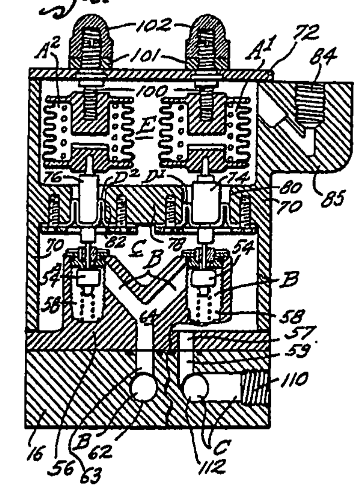


Fig.4.

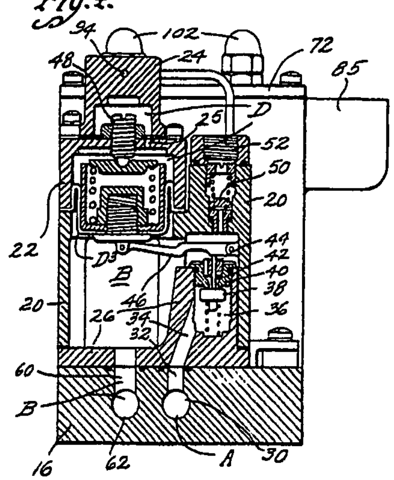
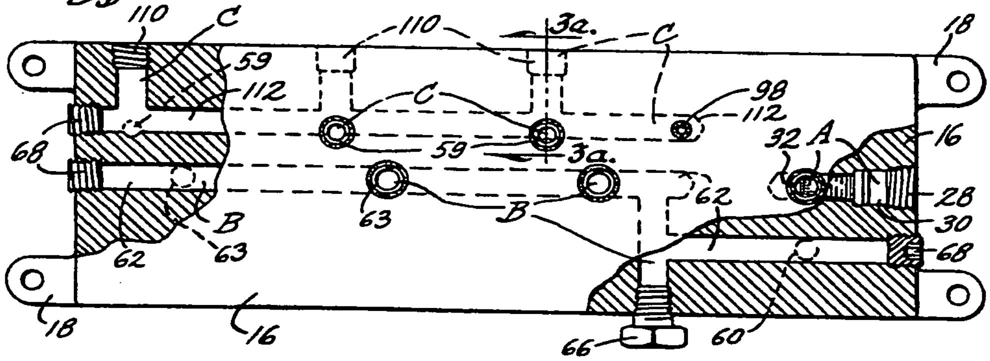


Fig. 5.



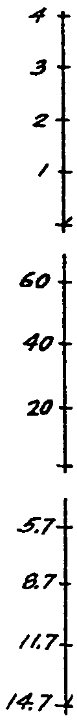


Fig. 6.

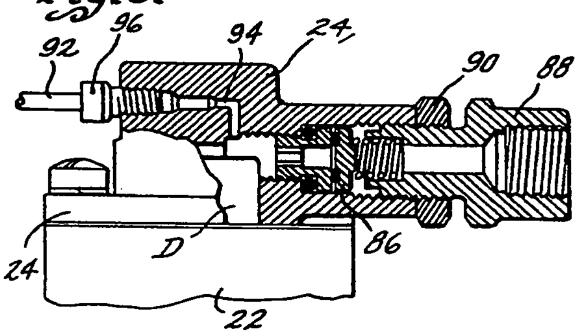


Fig. 7.

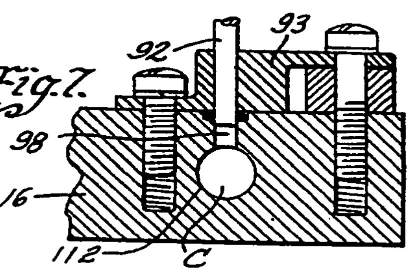
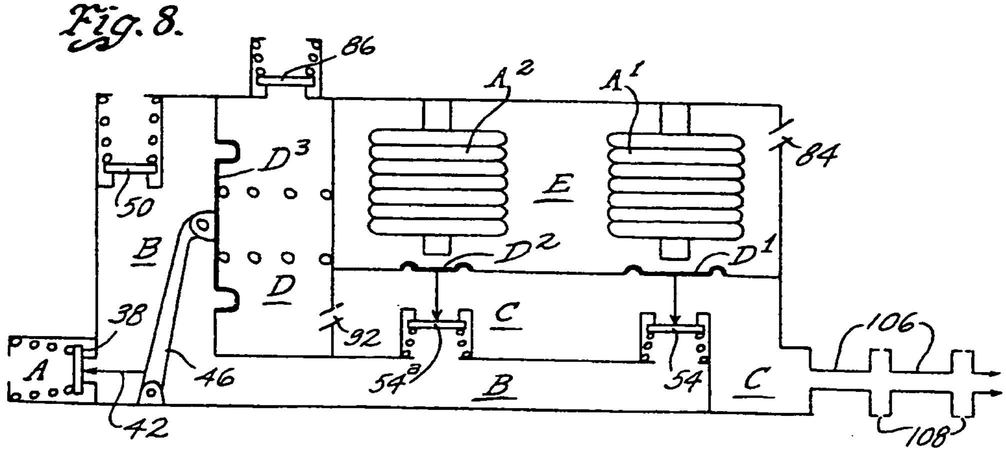


Fig. 8.



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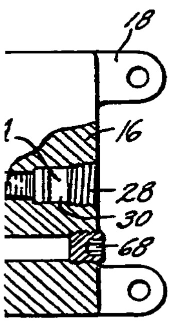
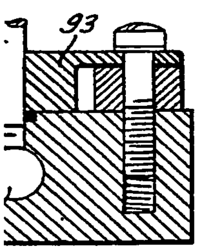




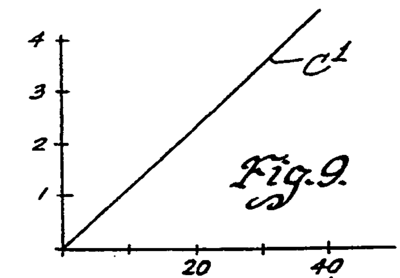


Fig.9.

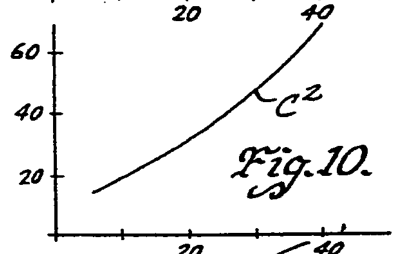


Fig.10.

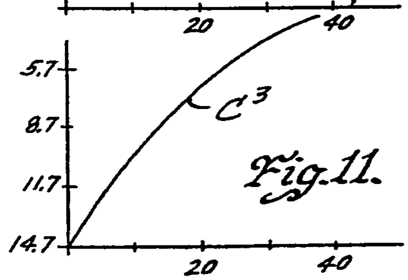


Fig.11.

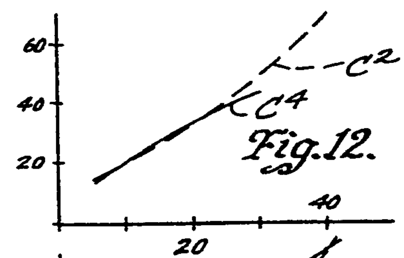


Fig.12.

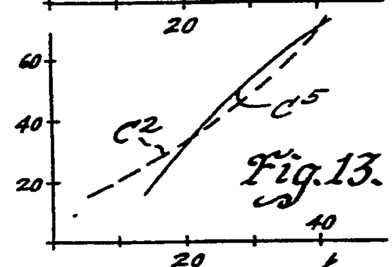


Fig.13.

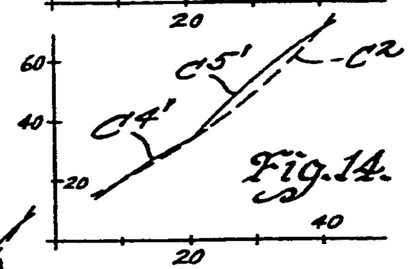


Fig.14.

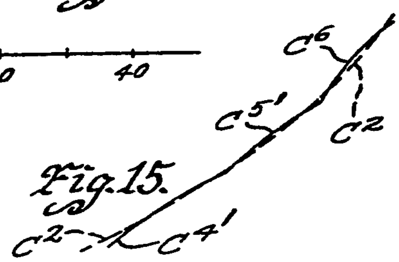
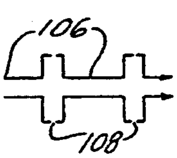


Fig.15.



865,084 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 2

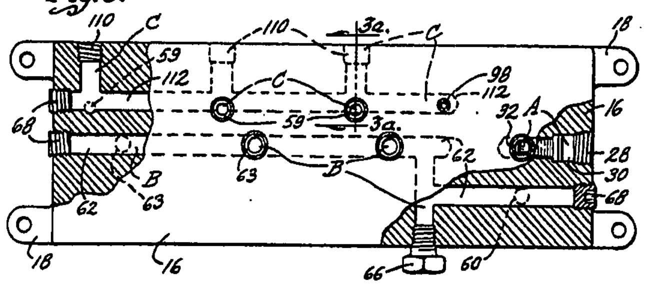


Fig. 5.

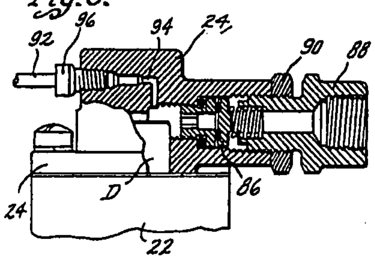


Fig. 6.

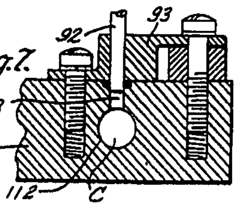


Fig. 7.

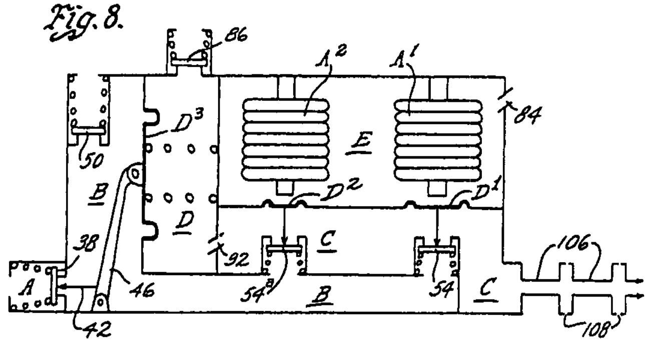


Fig. 8.

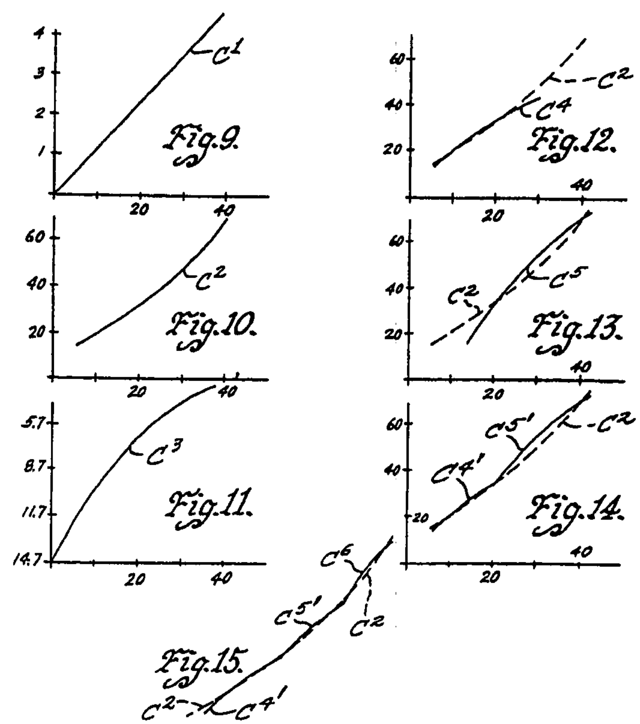


Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.